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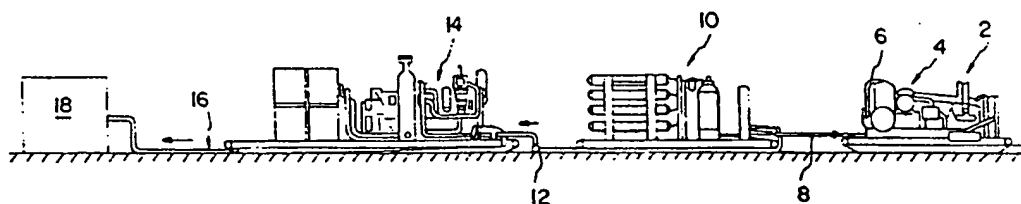
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(54) Title: NON-CRYOGENIC PRODUCTION OF NITROGEN FOR ON-SITE INJECTION IN DOWNHOLE DRILLING



(57) Abstract

There is disclosed a method for oil or gas drilling or the drilling of a geothermal well in which a compressed inert gas, produced by the non-cryogenic separation of air is delivered to the drilling region of the downhole.

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NON-CRYOGENIC PRODUCTION OF NITROGEN FOR ON-SITE INJECTION IN  
DOWNHOLE DRILLING

5           The present invention is directed to a method of  
drilling for oil, gas or geothermal wells which employs an  
inert gas in the drilling region to remove drill cuttings.  
The inert gas, typically nitrogen gas, is supplied on-site by  
the preferential separation of air using a non-cryogenic  
10 source of the inert gas such as a membrane or a pressure swing  
adsorption system.

          In the drilling for oil or gas or geothermal wells,  
the drilling apparatus requires a fluid in the drilling region  
around the drill bit to remove the drill cuttings. One such  
15 drilling fluid is drilling mud which is often used when large  
flows of water are present in the downhole (that is the region  
where drilling takes place below ground level). It has also  
been found that the injection of gas into the downhole results  
in faster drilling rates when substantial amounts of water are  
20 not present in the downhole.

          Air has been used as the principal downhole drilling  
fluid for low water content drilling. Straight air drilling  
requires only that air be compressed and circulated such that  
drill cuttings are lifted from the downhole free of liquids.  
25 The air can be combined with a surfactant, foaming agent,  
water and/or mud for different applications.

          The selection of air drilling systems over mud  
drilling systems is based on the feasibility of drilling the  
hole (for example the presence or absence of a substantial  
30 amount of water in the downhole as well as economics). The  
primary advantages of straight air drilling are greatly  
increased penetration rates, greater bit footage and fewer  
downhole drilling problems.

Downhole drilling with air, however, does have a number of disadvantages, one of the most important of which is the occurrence of downhole explosions or fire due to the presence of high levels of oxygen in air. Efforts have been made to reduce the hazards of air drilling by lowering the temperature of the air or by replacing air with an inert gas.

For example, J. Q. McGuire, Jr., U.S. Patent No. 3,612,192 discloses a process for air drilling in which the air is cooled to cryogenic temperatures. The frozen air not only reduces the threat of downhole combustion but also freezes the ground to prevent the influx of water. As is well known, cooling to cryogenic temperatures is costly and requires additional heavy equipment which may not be readily available, particularly when drilling takes place in remote locations.

Another approach to eliminating the hazards of using air as a drilling fluid is to employ an inert gas. Such systems are disclosed for example, in N.C. Wells, U.S. Patent No. 2,786,652 and J. G. Jackson, U.S. Patent No. 3,286,778. While the source of the inert gas (for example nitrogen gas) used in these systems is not set forth, it is common to use liquid nitrogen as the source of gas. Liquid nitrogen, however, is disadvantageous because it is considerably more expensive to use than air and difficult to obtain in remote locations.

An effort has been made to come up with alternative sources of nitrogen gas for use as a drilling fluid. H. E. Mallory, et al, U.S. Patent No. 4,136,747 discloses a method of drilling in which nitrogen gas is obtained from the exhaust gas of engines. While such methods are of interest, they have not been commercialized on a large scale because of the high cost, difficulty in implementation, and technical problems such as the corrosive nature of the products of combustion.

It would therefore be desirable to devise a method by which an inert gas, typically nitrogen gas, may be conveniently and efficiently supplied to the downhole of a drilling operation in a manner which eliminates the problems associated with cryogenic nitrogen and other sources of nitrogen gas.

The present invention is generally directed to a method for drilling for oil and/or gas or a geothermal well in which a compressed inert gas is delivered to the downhole. The inert gas is obtained from an on-site non-cryogenic source. In particular, the source of the inert gas is air which is preferentially separated into an inert gas rich fraction and an oxygen waste gas fraction such as by membrane separation or by pressure swing adsorption or the like.

The following drawings in which like reference characters indicate like parts are illustrative of embodiments of the invention and are not intended to limit the invention as encompassed by the claims forming part of the application.

Figure 1 is a schematic view of an embodiment of the invention showing an above surface apparatus for generating a nitrogen rich gas from an air-separation membrane to be delivered to a drilling region;

Figure 2 is a schematic view similar to Figure 1 in which a nitrogen rich gas is generated by a pressure swing adsorption unit;

Figure 3 is a schematic view of a two bed pressure swing adsorption system for generating a nitrogen rich gas;

Figure 4 is a schematic view of a surface equipment installation for delivering the inert gas to the drilling region; and

Figure 5 is a schematic view of a downhole drill stem arrangement showing the delivery of the inert gas to the drilling region.

5 The present invention is directed to the on-site non-cryogenic production of an inert gas, typically a nitrogen rich gas and its delivery as a drilling fluid in the drilling of oil and/or gas or geothermal wells. As used herein the term "nitrogen rich gas" shall refer to a gas containing predominantly nitrogen gas and no more than 10% oxygen gas by  
10 volume. The nitrogen rich gas is produced from air by a number of different methods including membrane separation, pressure swing adsorption, vacuum swing adsorption, and fuel cells.

15 Referring to Figure 1 there is shown an above ground installation for producing a nitrogen rich gas using membrane separation and for delivery of the nitrogen rich gas to the drilling region. A feed air compressor 2 includes an intake port 4 for receiving ambient air and a compressor 6 for pressurizing the air to a suitable pressure, typically in the  
20 range from 100 to 350 psig.

The compressed air is sent through a conduit 8 to an air separation membrane system shown generally by numeral 10, such as the high performance air separation membrane system manufactured by Generon Systems of Houston, Texas.

25 The membrane is composed of bundles of hollow fiber, semi-permeable membranes which are assembled parallel to a central core tube. The bundle is placed into an outer case to form an air separation module. The air is divided into two streams; a nitrogen rich stream and a stream rich in oxygen and water vapor.  
30

When the compressed air is introduced to the feed side of the membrane fibers, the air travels down the bore of the hollow permeable fibers. Oxygen, water vapor and other

"fast gases" pass through to the outside of the fibers. The oxygen-rich gas stream then flows through the fiber bundle to the periphery of the outer case of the separator system where it is discharged as a by-product.

5 While all but a small fraction of the oxygen passes through the membrane material to the exterior of the hollow fibers, most of the nitrogen present in the feed air is contained within the hollow fiber membrane. As a result, the nitrogen rich gas is effectively separated from the feed air  
10 and exits the membrane system 10 via a conduit 12 for entry into an optional booster compressor 14.

The booster compressor 14 is employed to elevate the pressure of the nitrogen rich gas. The pressure of the gas obtained from the air separation membrane system 10 is from  
15 100 to 200 psig. The booster compressor 14 is capable of raising the pressure of the nitrogen rich gas up to or exceeding 4500 psig and even as high as 10,000 psig, but typically in the range of from 1,000 to 2,000 psig. The highly compressed nitrogen rich gas leaves the booster  
20 compressor 14 via a conduit 16 and is sent to a surface equipment installation 18 of the drilling operation as explained in detail hereinafter.

The nitrogen rich gas may also be produced by a pressure swing adsorption system in accordance with the  
25 present invention. Referring to Figures 2 and 3, there is disclosed a pressure swing adsorption unit 20 having two beds "A" and "B". It should be understood, however, that the present invention is applicable to pressure swing adsorption units having an alternate construction such as a greater  
30 number of beds.

Referring to Figure 3, air from a source (not shown) is fed to a compressor 6 to raise the pressure of the air, to accumulate compressed air during the non-production phase and to output compressed air during peak loading of the beds. The

compressed air is fed to a storage vessel 22. The compressed air is then fed via the conduit 24, 26 to an outlet 28 leading to bed A and an outlet 30, leading to bed B. Each outlet 28, 30 is controlled by respective valves 32, 34. When valve 32 is opened, allowing the compressed air to reach bed A, valve 34 remains closed so that bed B may undergo regeneration during the depressurization phase of the pressure swing adsorption unit 20.

The compressed air enters the bed A through the open valve 32 via a conduit 36. The bed A contains at least one adsorption material capable of preferentially adsorbing oxygen and other waste gases. The preferred adsorbents are selected from molecular sieves and silica gel. As a result, substantially pure nitrogen passes out of the bed A through a conduit 38, a valve 40 and into a nitrogen storage vessel 42 via a product line 44 for passage via a conduit 82 to the optional booster compressor 14 shown in Figure 1.

While bed A is producing nitrogen gas, bed B is at atmospheric pressure. Upon completion of the nitrogen production cycle in bed A, the system undergoes equalization to raise the pressure in bed B to an intermediate pressure. This is accomplished by closing the nitrogen product valves 40, 46 and the compressed air intake valves 32, 34. Thus, the input of compressed air and the output of nitrogen product are temporarily suspended.

Equalization is accomplished by passing a portion of the pressurized gas from the top of the bed A via a conduit 38, valve 50, a conduit 52, restrictive orifice 54, through a conduit 56 and into the top of the bed B. In addition, pressurized gas is passed from the bottom of the bed A via the conduit 36, a valve 58, a conduit 60, a restrictive orifice 62 and a conduit 64 into the bottom of bed B.

Once equalization is completed so that bed A and B are at similar pressures, bed A undergoes regeneration by



depressurizing to atmospheric pressure to remove the oxygen enriched waste gases. This is accomplished by closing the equalization valves 50, 58 and opening a regeneration valve 66 for the bed A. The waste gas is then vented to the atmosphere through a conduit 68 and a restrictive orifice 70. As a consequence, the bed A is regenerated.

Further cleansing of the bed A may be made by passing a purge gas, such as substantially pure nitrogen gas, from a source 72, through conduits 74 and 76, respectively, a valve 78 and into bed A via the line 38. When the bed B is further cleansed, the purge gas passes through the conduits 74 and 76, respectively, a valve 80 and the conduit 56. After purging, the adsorbents are ready for adsorbing waste gases in a new nitrogen production cycle.

Since the pressure in bed B has been raised to an intermediate pressure, it is ready to receive compressed air. The compressed air is provided through the valve 34 and the conduit 64. It may be necessary, in order to get sufficient compressed air to quickly load bed B up to operating pressure, for the compressed air feed generated by the compressor 6 to be supplemented by compressed air already stored in the storage vessel 22.

Once bed B has been loaded, the valve 46 is opened, allowing product gas to enter the product line 44 via the conduit 56 from which it enters the storage vessel 42. A distribution conduit 82 extends from the storage vessel 42 to provide a flow of nitrogen rich product gas to the booster compressor 14 shown in Figure 1.

After nitrogen production in bed B is completed, the valve 46 is closed as is the valve 34 to stop the compressed air feed. The equalization circuit is activated by opening valves 50, 58 and the pressurized gas is fed from the top and bottom of bed B to bed A to raise the pressure therein to an intermediate pressure level. Bed B is then depressurized by

eliminating the oxygen rich waste gases which are sent via the conduits 64, 84 through a valve 86 to the atmosphere via the conduit 68 and restrictive orifice 70.

5           Thereafter, compressed air from the compressor 6 and the storage vessel 22 is fed to bed A through the valve 32 via the conduit 36 to raise bed A to the desired operating pressure thereby commencing the nitrogen production cycle from bed A which passes into the booster compressor 14.

10           The nitrogen rich gas, after compression up to as high as 10,000 psig in the booster compressor 14, is sent to surface equipment installation shown in Figure 4 then to the drill stem arrangement shown in Figure 5.

15           Referring to Figure 4, the high pressure nitrogen rich gas obtained from the booster compressor 14 is sent to the surface equipment 18 via a conduit 90 through a main block valve 92. The flow rate of the nitrogen rich gas is typically measured by an orifice meter 94. The metered nitrogen rich gas is sent through an adjustable choke 96 and a pressure shut off valve 98 before entering a standpipe 100. 20           Mud can be added to the standpipe 100 through a conduit 102 should drilling mud or aerated mud be required for downhole circulation or occasionally to create sufficient hydrostatic pressure head to terminate circulation, or "kill" the well.

25           The nitrogen rich gas is fed through a Kelly cock or swivel 104, through a Kelly string 106 and into a Kelly packer 108. The Kelly string is a square or hexagonally shaped pipe which can readily be rotated in the rotating Kelly packer 108. This causes the entire drill stem assembly 124 and the drill bit 138 (see Figure 5) to rotate during drilling 30           operations.

          The nitrogen rich gas continues to flow until it reaches a drill stem assembly 124 which is typically connected in lengths called pipe stands. The drill stem

assembly 124 is fed through the well head assembly (shown generally by numeral 110) which may contain a series of pipe rams, vents and choke lines. As will be explained hereinafter, there is provided an outlet 112 which is  
5 connected to a blooey line for discharging the exhaust nitrogen gas and drill cuttings.

The surface installation may optionally include an injector manifold 114 for injecting chemicals, such as surfactants and special foaming agents, into the nitrogen rich  
10 gas feed stream to help dissolve mud rings formed during drilling or to provide a low density, low velocity circulation medium of stiff and stable foam chemicals to cause minimum disturbance to unstable or unconsolidated formations.

Extending below the surface of the ground into  
15 the downhole is the drilling stem arrangement which provides a pathway for the flow of pressurized nitrogen rich gas to the drilling region. There is also provided a second pathway for the flow of nitrogen gas and the drill cuttings out of the downhole and away from the drilling operation.

Referring to Figure 5, the drilling stem  
20 arrangement shown generally by numeral 120 includes a surface pipe 122 and casing 123 and the drill stem assembly 124 running concentrically with and spaced apart from the surface pipe 122 and casing 123 to define a pathway 126 for the return  
25 nitrogen rich gas and the drill cuttings. The center of the drill stem assembly 124 provides a pathway 128 for the flow of nitrogen rich gas to the drilling region. At the end 130 of the drill stem arrangement 120 is the drilling region 132 which includes a conventional tool joint 134, a drill collar  
30 136 ad a drill bit 138.

In operation, the nitrogen rich gas produced by the air separation membrane system 10 or the pressure swing adsorption system 20 or other non-cryogenic system typically has a nitrogen content of at least 85% by volume, preferably

at least 95% by volume, and an oxygen content of no more than 10% by volume, preferably less than 5% by volume. The nitrogen rich gas is sent to a booster compressor 14 where the pressure is raised to as high as 10,000 psig or more, typically in the range of 1,000 to 2,000 psig. The pressurized nitrogen rich gas is sent to the surface installation equipment 18 where it is monitored and metered into the downhole through the pathway 128 within the drill stem assembly 124.

Because the nitrogen rich gas is under pressure, it swirls around the drilling region 132 with sufficient force and velocity to carry the drill cuttings upwards into the pathway 126. The drill cutting containing stream then exits the outlet 112 of the surface installation equipment 18 where it is carried to a blowby line and eventually discarded into a collection facility, typically at a location remote from the actual drilling site.

The production of a nitrogen rich gas in accordance with the present invention and its delivery to the downhole is less costly and more reliable than conventional systems using cryogenic nitrogen.

#### EXAMPLE

The flow rate of nitrogen rich gas to the drilling region of an oil and/or gas well or a geothermal well can vary over a wide range depending on the size of the downhole, the depth of the well, the rate of drilling, the size of the drilling pipe, and the makeup of the geologic formation through which the well must be drilled.

A typical drilling operation will require the production of from 1,500 to 3,000 standard cubic feet per minute (scfm) of nitrogen gas from an air separation system which can be anyone of a number of conventional systems

including an air membrane separation system or a pressure swing adsorption system.

5 The purity of the nitrogen gas may vary, but was nominally set at no more than 5% by volume of oxygen. The resulting nitrogen rich gas was then pressurized up to a pressure of from 1,500 to 2,000 psig before being passed to the drilling region.

10 An average drilling operation will take two weeks, although difficult geologic formations may require several months of drilling. The nitrogen rich gas delivery system was designed for continuous operation and all of the nitrogen rich gas was generated on-site without the need for external nitrogen replenishment required for cryogenically produced liquid nitrogen delivery systems.

CLAIMS:

1. A method for drilling for oil or gas or a geothermal well in which a compressed inert gas is delivered to a drilling region within a downhole, the improvement comprising:

(a) removing at least a substantial portion of the oxygen contained within a feed stream of air at the site of said drilling to produce an inert rich gas and an oxygen enriched waste gas; and

(b) delivering the inert rich gas to the drilling region within the downhole.

2. The method of Claim 1 wherein the inert rich gas is nitrogen rich gas.

3. The method of Claim 2 wherein step (a) comprises passing a feed stream of air through a membrane which preferentially separates nitrogen gas from the other gaseous components of air.

4. The method of Claim 2 wherein the step of removing at least a substantial portion of oxygen comprises passing a feed stream of air through a pressure swing adsorption unit containing an absorbent which preferentially adsorbs oxygen and other gases contained within the feed stream of air to form the nitrogen rich gas.

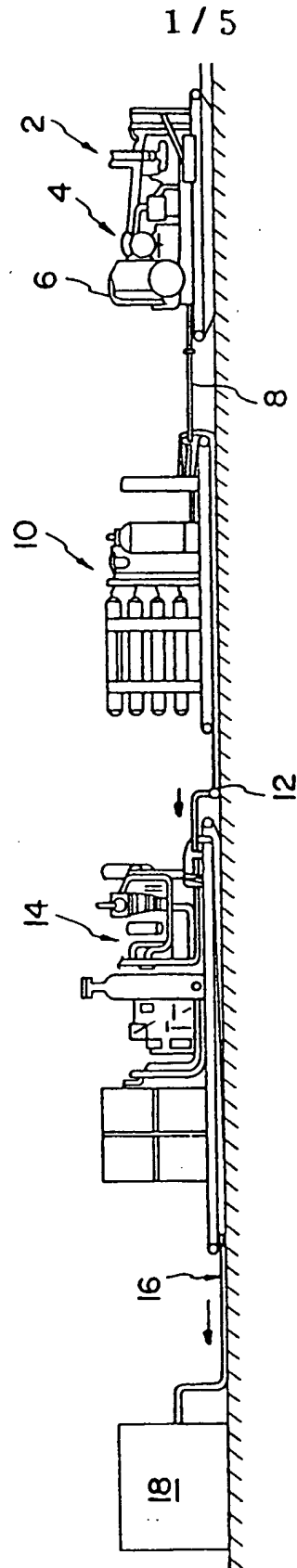
5. The method of Claim 2 wherein the nitrogen rich gas contains at least 85 volume percent of nitrogen.

6. The method of Claim 2 wherein the nitrogen rich gas contains at least 95 volume percent of nitrogen.

7. The method of Claim 2 further comprising raising the pressure of the nitrogen rich gas to at least 1,000 psig before delivering the nitrogen rich gas to the drilling region.

5 8. The method of Claim 2 wherein the pressure of the nitrogen rich gas is raised to 1,000 to 2,000 psig.

FIG. 1





2 / 5

FIG. 2

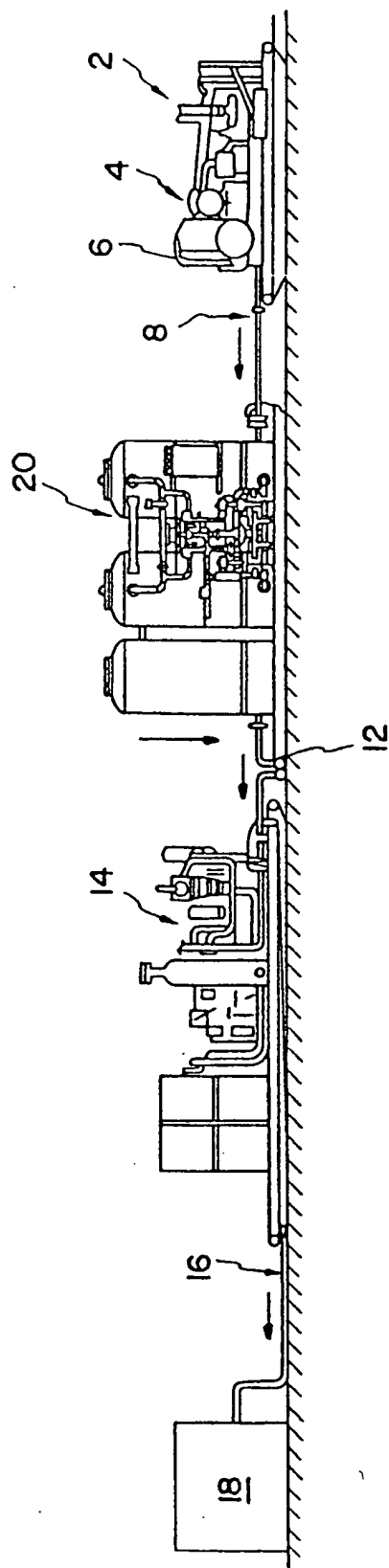
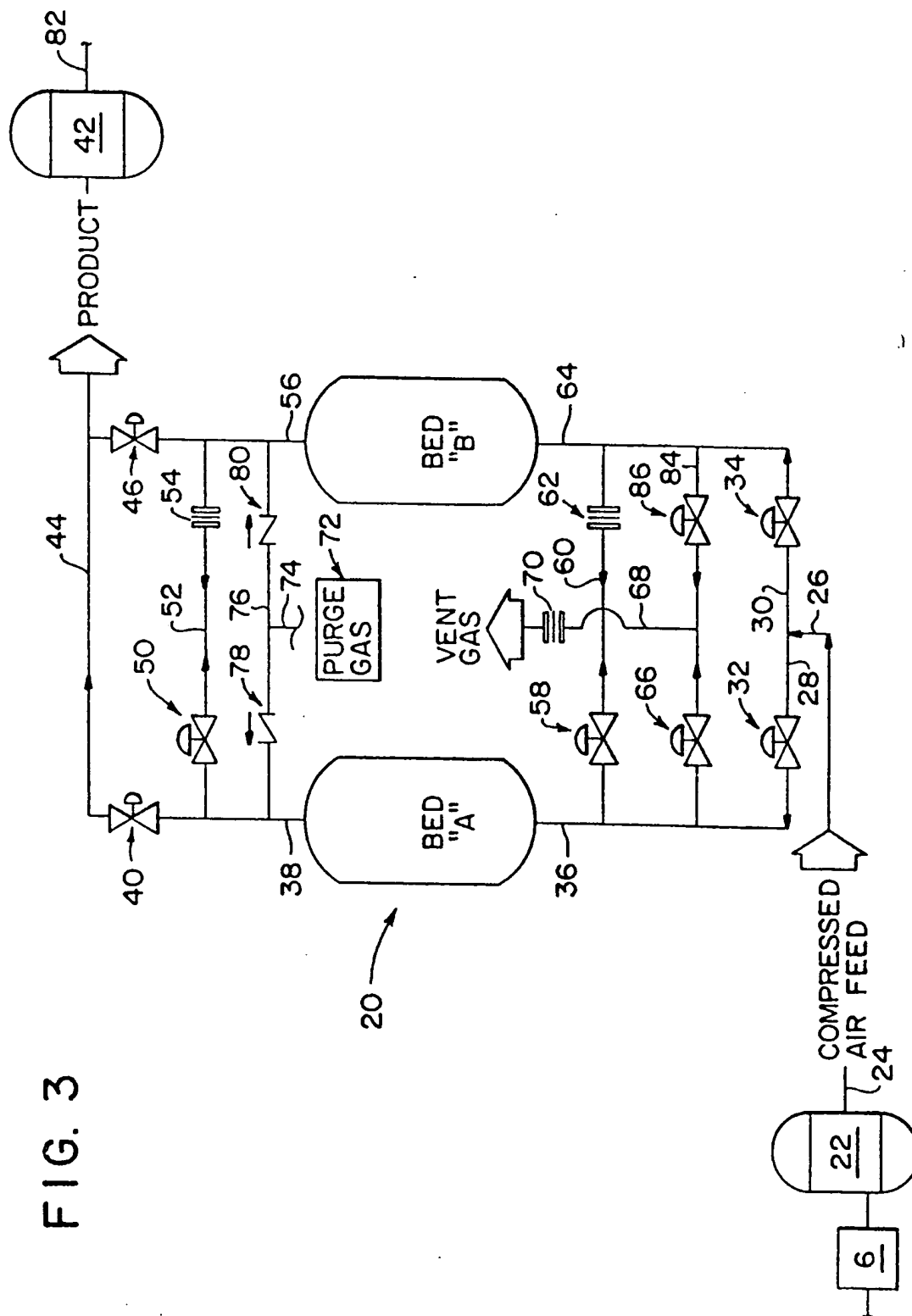


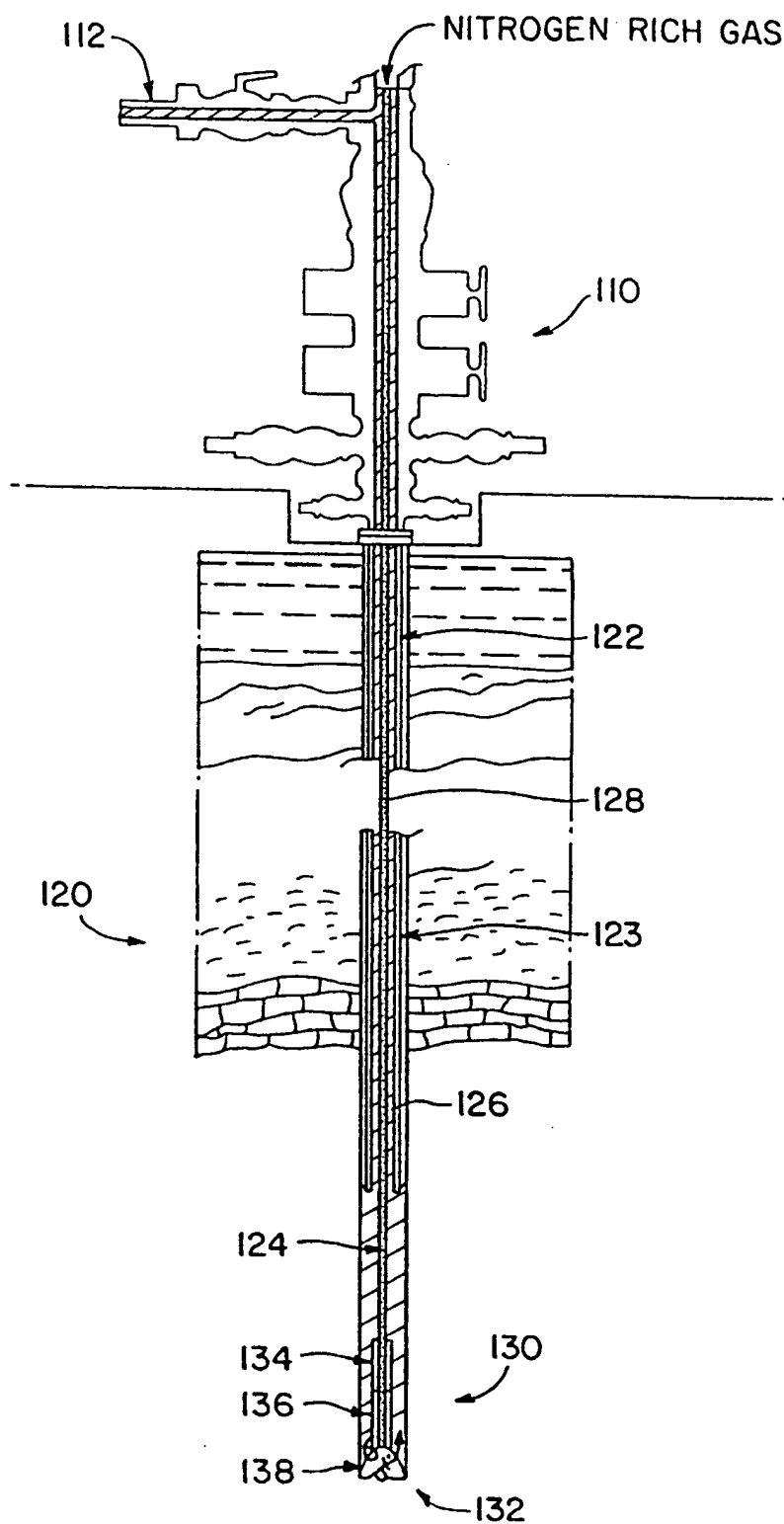
FIG. 3





5 / 5

FIG. 5



## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 94/06729

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 E21B21/00 E21B21/14 C09K7/08

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 E21B C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 136 747 (MALLORY) 30 January 1979 cited in the application see abstract; figures ----	1
A	US,A,3 286 778 (JACKSON) 22 November 1966 cited in the application see claim 1 -----	1

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US-A-4136747	30-01-79	US-A- 4350505	21-09-82
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